NOTE

ON THE

PERCEPTION OF MUSICAL SOUNDS.

BY

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Certain individuals appear to be incapable of appreciating musical sounds. They cannot distinguish one melody from another; and if by many repetitions of the melody in their hearing, they at last appear to know it, the addition of one or more of the parts of the harmony again renders the music unrecognisable to them. The question naturally arises, Is this defect owing to any peculiarity in the structure of the internal ear of persons so constituted which prevents them hearing certain sounds, or is it to be referred to the condition of the brain? On the other hand, many have what is termed a "fine ear," by which we understand the faculty of appreciating, remembering, and, in some cases, of successfully imitating musical sounds. Have those individuals the organ of hearing more delicately developed?

This physiological problem does not, in the present state of our knowledge of the minute structure of the organ of hearing in man, permit of being examined histologically. We would not probably find any appreciable histological difference between the internal structure of the ear of a genius in music and that of a person who could not distinguish one melody from another. So far as this method of inquiry is concerned, differences may exist, but the minute size of the ultimate recipients of sound-waves, and the vagueness of our present knowledge of the number of these in the depths of the cochlea, would prevent any one from noticing those differences.

It, therefore, occurred to me to examine this question by testing experimentally whether those individuals who profess to be unable to know music were incapable of hearing certain musical sounds, limited as regards pitch, within the extreme keys on the key-board of a piano. I have examined ten cases of this kind.

In a musical sound three elements have to be considered,—1*st*, loudness or intensity, which depends on the extent of vibration;

2*d*, pitch, determined by rate of vibration; and, 3*d*, quality, which depends on the orders, numbers, and relative intensities of the simple tones into which it can be resolved.

Up to the present point of this inquiry I have devoted attention chiefly to the element of quality. The apparatus I have employed was made by Georg Appunn of Hanau. It is a long wooden box inclosing a row of vibrating tongues or free reeds, which can be thrown into action by propelling air into the box by means of a bellows. The note produced by the longest reed, No. 1, is that obtained by a vibrating cord, of a certain length, thickness, and tension, as in a monochord, and corresponds to C^2, having 32 vibrations per second. On dividing the cord into 2, 3, 4, 5, 6, &c. equal segments, each segment, when caused to vibrate, will produce a note composed of 2, 3, 4, 5, or 6 times the number of vibrations in No. 1. This apparatus is capable of producing 64 tones, a larger number than are included within the key-board of a piano. The names and number of vibrations per second of these tones in this apparatus is as follows:—

No.			
1.	C^2	32,	Fundamental tone.
2.	C^1	64,	Octave.
3.	G^1	96,	Fifth above No. 2.
4.	C^0	128,	Fourth above No. 3.
5.	e^0	160,	Major third above No. 4.
6.	G^0	192,	Minor third above No. 5.
7.	C^0	224	
8.	C^1	256	
9.	D^1	288	
10.	e^1	320	
11.	F^1+	352	
12.	G^1	384	
13.	a^1-	416	
14.	b^1	448	
15.	h^1	480	
16.	C^2	512	
17.	Des^2	544	
18.	D^2	579	
19.	Es^2-	608	
20.	c^2	640	

No.		
21.	f^2	672
22.	F^2+	704
23.	Fis^2	736
24.	G^2	768
25.	gis^2-	800
26.	a^2-	832
27.	a^2	864
28.	b^2	896
29.	Ais^2	928
30.	h^2	960
31.	H^2	992
32.	C^3	1024
33.	C^3+	1056
34.	Des^3+	1088
35.	d^3-	1120
36.	D^3	1152
37.	D^3+	1184
38.	Es^3-	1216
39.	e^3-	1248
40.	e^3	1280
41.	E^3+	1312
42.	f^3	1344

No.			No.		
43.	f^{3+}	1376	54.	A^3	1728
44.	F^{3+}	1408	55.	A^{3+}	1760
45.	Fis^3	1440	56.	b^3	1792
46.	Fis^{3+}	1472	57.	B^3	1824
47.	g^3	1504	58.	Ais^3	1856
48.	G^3	1536	59.	Ais^{3+}	1888
49.	As^{3-}	1568	60.	h^3	1920
50.	Gis^{3-}	1600	61.	H^{3+}	1952
51.	As^3	1632	62.	H^{3++}	1984
52.	a^{3-}	1664	63.	c^{4-}	2016
53.	a^3	1696	64.	C^4	2038

I have also a series of 64 resonators, tuned to these 64 tones, and having corresponding numbers. When tone No. 12 on the overtone apparatus is sounded, and the narrow end of resonator No. 12 is placed in the ear, the instrument sings into the ear of the observer with great intensity. I have thus in the group of resonators an apparatus for analysing any compound musical note into its constituent tones; and, in the overtone apparatus, I have a means of checking the sensation of the listener by sounding, with much greater intensity, the tone corresponding to the resonator by which he heard any particular tone in a compound note. The method I adopted was,—1*st*, to strike a note on the piano, which, of course, consisted of a fundamental tone, and of certain overtones; 2*d*, to allow the person whose ear was being examined to listen with the various resonators until he selected one by which he heard a tone (one existing in the note, and strengthened in intensity by the resonator); 3*d*, after the listener had satisfied himself that he clearly heard the overtone ringing in his ear, the note on the piano was arrested, the stop of the overtone apparatus corresponding to the overtone was withdrawn, so as to sound the overtone, and the listener had to decide whether or not this was the same sound as the one he heard when listening to the musical note. The result in the ten cases I examined was as follows:—In nine of the cases the overtone was readily perceived; and in the tenth, the lower overtones of the series were observed directly, whereas the higher overtones were not noticed by means of the resonator, but were clearly observed when those overtones were sounded on the overtone apparatus. This individual asserted he had often noticed he was deaf to very highly-pitched sounds which other people said they heard.

These results indicate that, so far as the structure of the ear is concerned, those individuals who are said not to know one note from another, are equally capable, by the use of resonators, of analysing a compound musical note—that is, of hearing the various tones of which it is composed—with those who have a good ear. Physiologically, they seem to be capable of splitting up, unconsciously, the compound vibration into the simple vibrations, the rates of which are once, twice, or thrice that of the fundamental note.

The next point which I examined was regarding the perception by persons having no musical ear of difference and summation tones, which, as is well known, play an important part in the theory of concord and discord.

If, on the overtone apparatus, two tones of different pitch are sounded, a third and deeper tone may be frequently observed. These tones were first discovered by a German organist, Andreas Sorge, in 1740. For example, if 2 : 3, or 3 : 4, or 6 : 7, or 7 : 8, &c., are sounded, a third and deeper tone may be perceived by the use of a proper resonator, which will be always found to be $C_2 = 1$; that is, this combination tone is produced by 32 vibrations per second, the difference between the respective vibration numbers of the tones 2 : 3, or 3 : 4, or 6 : 7, &c. I have found that the difference tone heard with greatest distinctness corresponds to one produced by 128 vibrations per second. For example, on sounding 16 : 20, or 24 or 28, or 32 and 36, with resonator No. 4, I can distinctly hear the tone corresponding to No. 4 = 128 vibrations per second in each case. I have found no marked difference between non-musical and musical individuals in the perception of difference tones, except as regards intensity. I had the opportunity of examining two persons of marked musical ability, who could distinguish, by great attention, without the aid of resonators, difference tones to the 6th of the series, and who could observe difference tones, 2, 3, and 4, with comparative ease. Non-musical persons did not observe these difference tones without the use of resonators to add to their intensity; and, in one case, the person could not hear them at all. In addition to these primary difference tones, I have met with only one individual who could hear what are termed secondary and tertiary difference tones, and he could not hear these without apparently a strong effort of attention. They were as follows:—On sounding 16, $C^2 = 512$ vibrations per second, and 20, $c^2 = 640$, he heard $C^0 = 128$, that is, $20 - 16 = 4$. By using resonator No. 12, he heard $12 = 384$, that is $16 - 4 = 12$; and on using resonator No. 8, he heard very feebly 8, that is $12 - 4 = 8$. When C^2 and e^2, that is tones corresponding to 512 and 640 vibrations per second, were sounded in this person's ears, he heard other three tones with the use of resonators, namely, those produced by 128, 256, and 384 vibrations per second.

But when two tones are sounded, in addition to a tone produced by a vibration number equal to the difference between the vibration number of the two, another tone is produced, the vibration number of which is equal to the sum of the vibration numbers of the two primaries. This tone is called a summation tone. For example, on sounding $4 = 128$ and $6 = 192$ vibrations per second, by using resonator No. 10 = a tone having 320 vibrations per second may be distinctly heard. Thus, 2 : 3, and 3 : 4, and 5 : 9, will produce sounds heard by resonators Nos. 5, 7, and 14, respectively. I have found that non-musical people can hear these summation tones with great distinctness if increased by resonators. They can hear the lower order of summation tones much more easily than the higher order. For example, all could hear the summation tone 2 (64) : 3 (96) = 5 (160) –, or 4 (128) : 6 (192) = 10 (320); but only four out of the ten could hear 7 (224) + 8 (256) = 15 (480), and 8 (256) + 9 (288) = 17 (544). Only one out of the ten could hear 30 (960) + 28 (896) = 58 (1856), and none could hear 32 (1024) + 30 (960) = 62 (1984). I observed also that they could hear the higher summation tones only when the intensity was increased to as great an extent as possible. The two musical persons examined were able to hear all these sounds with ease, with even diminished intensity.

According to Helmholtz, there are secondary and tertiary summation tones, which spring from combinations of the primary summation tones with its elements. Thus, 3 (96) : 5 (160), with the overtone apparatus, give 8 (256); 3 (96) and 8 (256) give 11 (352); 5 (160) and 8 (256) and give 13 (416). Therefore, when 3 (96) and 5 (160) are sounded, according to this statement, the listener with resonators may hear 3 (96), 5 (160), 8 (256), 11 (352), and 14 (448). I have examined this and various other combinations. I can with my own ears hear, by using the appropriate resonator, the primary combination series quite distinctly, but no farther. The secondary tones I have never heard. Eight out of the ten non-musical people I have examined have heard the primary series; the other two said they thought they could hear the second. The two musical persons asserted they could hear the tones distinctly.

If then "the presence of overtones confers on music its most characteristic charms," as stated by Sedley Taylor,* it appears to me that non-musical persons, when aided by resonators, are as capable as musical persons of recognising the existence of certain of these overtones. The difference between the two classes of listeners is either—(1), that the intensity of the overtone requires to be greater to be appreciated by a non-musical than by a musical person; or (2), that musical persons, by previous education of the sense, are better able to appreciate distinctions of sound. Non-musical persons seem to be incapable of noticing the existence of the higher overtones, which are, of course, much less intense than the lower overtones. They are incapable of observing the difference and summation tones having high vibration numbers. Thus, so far as the mere perception of musical sounds, and of those secondary vibrations, which produce overtones, and give quality to the fundamental tone, or duad, or triad, &c., is concerned, non-musical persons are affected by the vibrations just as musical persons are affected. The only difference I have noticed between the two is that of intensity. A musical person hears tones of low intensity, such as the higher overtones, quickly, and apparently without difficulty; whereas, a person who is non-musical hears the lower overtones, but he cannot hear the upper at all, even with the aid of a resonator. The question of intensity of tones and overtones I have still under experimental inquiry. These researches indicate that in the sense of hearing there is no state analogous to that of colour-blindness in the eye.

* Sound and Music: A Non-Mathematical Treatise on the Physical Constitution of Musical Sounds and Harmony, &c. By Sedley Taylor, M.A., &c. London, 1873.